Working Paper

An Exploratory Study of Cost-Benefit Analysis of Landscape Restoration

Priscilla Wainaina, Eunice Gituku, Peter Minang

World Agroforestry

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Acronyms and Abbreviations

AFR100	African Forest Landscape Restoration Initiative
ANR	Assisted Natural Regeneration
BAU	Business as usual
C	Carbon
CBA	Cost-benefit Analysis
CGIAR	Consortium of International Agricultural Centres
CIFOR	Center for International Forestry Research
CVM	Contingent valuation methods
ELD	Economics of Land Degradation
ER	Ecosystem Restoration
ES	Ecosystem services
FAO	Food and Agriculture Organization of the United Nations
FLR	Forest Landscape Restoration
FMNR	Farmer-managed Natural Regeneration
FGDs	Focus group discussions
FTA	Forests, Trees and Agroforestry
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
ICRAF	World Agroforestry
IIED	International Institute for Environment and Development
IUCN	The International Union for Conservation of Nature
KIIs	Key Informants Interviews
NPV	Net Present Value
NTFPs	Non-timber forest products
NYDF	New York Declaration on Forests
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SER	The Society for Ecological Restoration
SLM	Sustainable Land Management

SWC	Soil and Water Conservation
TEEB	The Economics of Ecosystems and Biodiversity
TEER	The Economics of Ecosystems Restoration
TEV	Total Economic Value
UK	United Kingdom
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
USA	United States of America
WMO	World Meteorological Organization
WRI	World Resources Institute
WTP	Willingness to pay

Abstract

Owing to the increasing demand for restoration globally and limited resources available, there is a need for economic analysis of landscape restoration to help prioritize investment of the scarce resources. Cost-benefit analysis (CBA) is a commonly applied approach in the economic analysis of landscape restoration as well as for strategizing and prioritizing resource allocation. However, despite the growing number of studies and projects on restoration globally, studies on cost-benefit analysis of landscape restoration are relatively few. A systematic review of the cost-benefit analysis of landscape restoration was conducted to understand the extent and coverage of existing studies, as well as gaps. After a comprehensive search and filtering of the studies, 31 that met the various guidelines of CBA of landscape restoration were identified. These are distributed across different regions globally, with the majority of them in Sub-Saharan Africa and Asia. The CBA studies reviewed were conducted for different types of restoration options/strategies including; reforestation and afforestation, agroforestry, biofuel agroforestry, participatory forest management, establishment of woodlots, sustainable land management practices, natural regeneration, assisted natural regeneration, mangrove restoration, clearing of invasive alien species, and restoration of urban and buffer areas. A larger proportion of the studies focused on agroforestry, reforestation and afforestation. For some restoration options, all the studies conducted reported positive net present value (NPV); agroforestry (8), soil and water conservation (5), mangrove restoration (3) and alien vegetation clearing (3). However, for some of the restoration strategies, several studies reported negative NPV: in reforestation and afforestation, the number of studies that reported positive NPV (4) was equal to those that reported negative NPV (4).

In terms of accounting for benefits accruing from restoration, majority of the studies accounted for the use values only (either direct use or indirect use or both), and only around 16% accounted for non-use values. This is because non-use values and some of the indirect use values are not easy to quantify since they do not have a market price. Accounting for the total economic value of a project is particularly useful for large-scale restoration initiatives where the benefits accrue to the broader public beyond the targeted stakeholders. Similarly, for cost components, relatively few studies accounted for the opportunity cost component. This is probably because it is often difficult to estimate this cost since it is not a direct cost and for some land uses the opportunity cost may be negligible, especially if the land is highly degraded. Further still, some restoration projects fail to account for maintenance and monitoring costs since they view restoration as a one-time cost activity, as opposed to a continuous activity where maintenance and monitoring costs are significant. Future cost-benefit analysis studies ought to account for all the benefits and cost components attributable to restoration; otherwise, profitability of restoration projects could either be over- or under-stated.

Similarly, lack of reliable data owing to poor data-keeping during the restoration period also affects CBA results. This requires data over several years, and most projects do not keep such records. Hence, even for ex-post CBA evaluations, a lot of predictions and assumptions are involved in data generation. Thus, there is need to adopt standardized methods of data prediction if the results are to be comparable across different restoration projects that would guide decisions in the allocation of funds. An ongoing project, ‘The Economics of Ecosystem Restoration (TEER)’ aims to “offer a reference point for the estimation of costs and benefits of future ER projects in all major biomes, based on information from comparable initiatives on which data are collected through a standardized framework”.

Keywords: Cost-benefit analysis, Landscape restoration; Global; Systematic review

Acknowledgments

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1.0 Introduction

There is a growing demand for restoration, globally. It is aimed at stopping further degradation and reversing degradation. Over the last decade, there have been global restoration initiatives, including 'The Bonn Challenge' and 'The New York Declaration on Forests (NYDF)'. The Bonn Challenge is a global effort to bring 150 million hectares of the world's deforested and degraded land into restoration by 2020, and 350 million hectares by 2030[1], while the NYDF is a political declaration among governments, companies, indigenous peoples and civil society to take action to halve the loss of natural forests by 2020 and halt it by 2030[2]. Within Africa, the African Forest Landscape Restoration Initiative, AFR100, aims to restore 100 million hectares of land in Africa by 2030[3]. Specific countries have also set definite restoration goals; for example, Kenya has committed to restoring 5.1 million ha of degraded land[4], while Malawi committed to about 4.5 million ha by 2030 (Ministry of Natural Resources, Energy and Mining-Malawi, 2017).

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER and Policy Working Group, 2004). The goal is to repair the ecosystem with respect to its integrity and health, and to reverse land degradation, increase the resilience of biodiversity, and deliver important ecosystem services (Ciccarese et al., 2012; Wortley et al., 2013). Ecological restoration also includes forest and landscapes restoration. This is a process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes (Barrow et al., 2002). A key feature of forest and landscapes restoration is that a combination of forest and non-forest ecosystems, land uses, and restoration approaches can be accommodated within a landscape to achieve sustainable food production, ecosystem services provisioning, and biodiversity conservation (Chadzon et al., 2017).

Forest landscape restoration is not just a matter of planting trees; it also involves assisting in the recovery of a damaged or destroyed ecosystem. Restoration activities range from small-scale local initiatives carried out by individuals or community groups, through to regional, country and even global activities involving multiple agencies and large numbers of people (Menz et al., 2013). Restoration can either be achieved through natural regeneration or active restoration. Natural forest regeneration is the spontaneous recovery of native tree species that colonize and establish in abandoned fields or natural disturbances. This process can also be assisted natural regeneration, where it is assisted through human interventions such as fencing to control livestock grazing, weed control and fire protection (Shono et al., 2007). Active restoration, on the other hand, involves human contribution and considerable cost in terms of labour and time (Holl and Aide, 2010). It may require planting of nursery-grown seedlings, direct seeding, and/or the manipulation of disturbance regimes (for example,

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[1] www.bonnchallenge.org
[2] www.nydfglobalplatform.org
[3] http://afr100.org/
[4] https://afr100.org/content/kenya

thinning and burning) to speed up the recovery process. This usually involves costs to establish the vegetation structure, reassemble local species composition, and/or catalyze ecological succession.

Effective restoration should aim at the re-establishment of fully functioning ecosystems. To ensure effective forest restoration and achieve sustainability and resilience into the future, Suding et al. (2015) advocates for four principles of restoration; 1) restoration should increase ecological integrity; 2) restoration should be sustainable in the long term; 3) restoration ought to be informed by the past and future; and 4) restoration benefits and engages society through direct participation. Ecological integrity has been defined as the “ability of an ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of a natural habitat” (Dellasala et al., 2003).

When making a decision on the restoration strategy to be employed, several factors ought to be considered; specific ecosystem resilience, land-use history, landscape context, aim of the restoration and available resources (Holl and Aide, 2010). Various landscape restoration options/strategies have been practised globally, depending on these factors. Table 1 presents a summary of some of the commonly practised FLR options/strategies in different land use or ecosystem types adapted from FAO & Global Mechanism of the UNCCD (2015) and Gromko et al. (2019). A detailed explanation of most of these FLR practices and their restoration goals is provided by Gromko et al. (2019).

Table 1: Landscape restoration options for different land-use types

Land use/ecosystem type	**Landscape restoration options/strategies**
Forest land	• Afforestation and reforestation • Planted forests and woodlots • Natural regeneration • Silviculture • Assisted natural regeneration/reclamation/rehabilitation
Agricultural land	• Agroforestry • Integrated soil fertility management • Climate-smart agriculture • Improved fallow • Extended rotations in plantations • Farmer-managed natural regeneration (FMNR)
Protective land and buffers	• Mangrove restoration • Watershed protection • Erosion control • Bamboo planting along water bodies and wetlands
Urban areas	• Green and blue infrastructure in urban areas
Wetlands	• Wetlands restoration and conservation

Freshwater (rivers/lakes)	• River and lake restoration • Sediment management • Pound restoration • Integrated watershed management
Grasslands and shrublands	• Assisted natural regeneration

Adapted from FAO & Global Mechanism of the UNCCD (2015) and Gromko et al. (2019)

Due to the increasing demand for restoration globally, and limited resources available, there is need for economic analysis of landscape restoration to help prioritize the scarce resources accordingly. Cost-benefit analysis is the commonly applied approach in the economic analysis of landscape restoration. However, relatively few studies have conducted cost-benefit analyses (CBAs) of restoration projects. Yirdaw et al. (2017) conducted a review of the rehabilitation of degraded dryland ecosystems. They found that while numerous studies have been conducted on restoration and rehabilitation of degraded ecosystems, there remains a gap in cost-benefit analysis of these interventions. This has primarily been attributed to lack of data. For example, in a review of more than 2,000 restoration case studies, 'The Economics of Ecosystems and Biodiversity' (2009) it was discovered that less than 5% provided meaningful cost data, and none provided an analysis of both costs and benefits (Birch et al., 2010).

While CBA continues to be a primary approach for economic evaluation, adequate use of the tool requires a clear understanding of its limitations and pitfalls (World Meteorological Organization -WMO, 2007). To understand the extent and coverage of existing CBA studies, a systematic review of research on cost-benefit analysis of landscape restoration was conducted. From the entire systematic review process, 31 publications that meet the guidelines of the CBA were selected. From the review, gaps in existing CBA studies on restoration and how further research can address these gaps will be highlighted.

2.0 Economics of Landscape Restoration

2.1 Why the economics of landscape restoration matters

The main purpose of economics is the efficient allocation of scarce resources. Competition arises when there is scarcity, and as a result, the available resources must be rationed. Rationing calls for decisions in choices and allocation, and trade-offs are unavoidable. Restoration is generally a costly undertaking, partly because it often begins after the environmental degradation is well-advanced and expensive to reverse, and often labour- and resource-intensive (Crookes et al., 2013). Furthermore, restoration usually requires large investments upfront and has long lags before generating benefits.

Forest degradation, soil erosion, peatland, wetland drainage and salinization have been the leading causes of land degradation globally over the past 50 years. This has affected almost a quarter of the world's total land area, and the damage is felt through the loss of ecosystem goods and services. The damage costs the world an estimated US$6.3 trillion a year (8.3% of global GDP in 2016) in lost ecosystem service value, which includes climate regulation, clean air, recreational opportunities, freshwater and fertile soils (Ding et al., 2017). In addition, due to land degradation, the livelihoods of about half a billion people, especially poor populations who depend on agricultural and forestlands are jeopardized (FAO, 2017). Decreasing land productivity threatens water and food security, destabilizes sustainable development and results in civil conflicts and human migration.

Numerous environmental, economic and social benefits are generated when degraded lands are restored. These benefits may range from conservation of biodiversity, creation of jobs, improvement in agricultural productivity, and so on. Restoring degraded forests generates an estimated US$7–30 in economic benefits for every dollar invested. Despite this favourable benefit-cost ratio, funding for landscape restoration falls short by about US$300 billion a year (Ding et al., 2017). Investment is inadequate for several key reasons. For example, many of the benefits are public goods, which are difficult to monetize; the long-term nature of investments does not match investors' desire for liquidity, and projects are perceived to be risky. Economic analysis can encourage investment in restoration by clearly laying out the benefits and costs of restoration projects and their distribution among stakeholders. Cost-benefit analysis is the most commonly applied tool in analyzing the economics of land restoration.

Funding sources for investment in landscape restoration include: 1) Private finance – capital is managed mainly to earn a financial return for the investor; 2) Public finance where funding comes from government bodies. Public finance can further be divided into international donor support and domestic public expenditure. In this, public investments are largely made to generate economic, environmental and social benefits for the public. However, there may be a return to the government; 3) Philanthropic finance, which is charitable giving by individuals or organizations, typically with no intention of earning a financial return (Gichuki et al., 2019). Regardless of the source of funding, it is important to prioritize restoration needs.

2.2 Steps in conducting cost-benefit analysis of landscape restoration

Verdone (2015) outlines nine steps for cost-benefit analysis in landscape restoration:

1) Specify the set of restoration transitions: Define which degraded land uses will be restored and the activities that will be used to restore them

2) Define the stakeholders who will be affected by restoration: Define the groups of people who will be affected by the restoration transitions

3) Catalogue the impacts and define how they will be measured: Which impacts matter most to the stakeholders who will be affected by restoration and what units of measurement are most useful for measuring them?

4) Predict the impacts quantitatively over the time horizon of the project: Use ecosystem service models, household surveys, stakeholder engagement and other estimation methods to quantify the expected impacts of restoration activities

5) Monetize all the impacts: Use appropriate direct and indirect methods to value the estimated impacts

6) Discount benefits and costs to obtain present values: Select appropriate discount rates to make streams of future benefits and costs comparable at the present moment

7) Calculate the Net Present Value of each alternative: Subtract the discounted stream of implementation, transaction and opportunity costs from the discounted stream of benefits as shown in the equation below.

$$Net\ Present\ Value = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

Where B_t is the benefits from restoration at time t; r is the discount rate, C_t is the total restoration costs at time t.

8) Perform sensitivity analysis: The results of the CBA depend on assumptions, and the sensitivity of the results to changes in the underlying assumptions should be evaluated

9) Make policy recommendations: From a Pareto-efficiency perspective, the restoration activities with the largest NPV should be recommended.

2.3 Financial versus economic cost-benefit analysis

There exist similar features between financial and economic analyses. In both, the net benefits of a project investment are estimated. The estimation is based on the difference between with-project and without-project situations (World Meteorological Organization-WMO, 2007). However, in financial cost-benefit analysis of projects, benefits and costs are compared to the enterprise. In economic cost-benefit analysis, benefits and costs are compared to the whole economy. While conducting both analyses, the assumption of constant prices is made. In both situations, the techniques of evaluating costs and benefits through the discounting method remain the same.

The true value that a project holds for the society is highly considered in an economic analysis. It subsumes all members of society and measures the project's positive and negative impacts in terms of willingness to pay (WTP) for units of increased consumption, and to accept compensation for foregone units of consumption (World Meteorological Organization-WMO, 2007). Importantly, economic analysis covers the costs and benefits of goods and services which have no market price. In financial analysis, the project's sustainability and balance of investment is checked using market prices. In economic analysis, the legitimacy of using national resources in a certain project is measured using economic price which has been converted from the market price by excluding tax, profit, subsidy, etc. In financial analysis, the taxes and subsidies included in the price of goods and services are integral parts of financial prices, but they are treated differently in an economic analysis (World Meteorological Organization-WMO, 2007).

There is also a significant difference between financial and economic analysis in the way they treat their external effects (costs and benefits), e.g., favourable effects on health. Such externalities, health effects and non-technical losses tend to be valued in economic analysis. Both financial and economic analyses are supposed to include such externalities (side effects). AlsoIn addition, economic and financial returns in both analyses do not converge. This is because what counts as a benefit or a cost to the project operator does not necessarily count as a benefit or cost to the economy. When restoration is viewed through a financial accounting lens that ignores public values and the inter-generational nature of restoration, the conclusions that are drawn tend to favour investing in less restoration than society would prefer (Verdone and Seidl, 2017). In this review, we consider those studies that conducted an economic CBA. However, both analyses are complementary. For a project to be economically viable, it must be financially sustainable.

2.4 Challenges in conducting CBA of restoration

Forest Landscape Restoration activities are often misunderstood as involving high up-front costs and low rates of return; these ideas persist because few evaluations of restoration activities include a comprehensive and objective accounting of restoration's ecological and economic impacts. While CBA continues to be a primary approach for economic evaluation, adequate use of the CBA approach requires a clear understanding of its limitations and pitfalls (World Meteorological Organization-WMO, 2007). Conducting the CBA of restoration can be challenging due to a number of reasons.

First, CBA of restoration attempts to model or estimate the future; therefore, a certain degree of uncertainty is involved. CBA is based on certain assumptions which vary in their degree and level of confidence. During the process of data collection, key stakeholders are usually consulted for accuracy improvement and to increase their buy-in (Gromko et al., 2019). For example, unforeseen events and climate change may affect productivity in ways that are difficult to predict, and these should be taken into account. The assumptions made during CBA include political and/or social assumptions which may not necessarily hold.

The second challenge is that while conducting CBA of restoration, it is difficult and controversial to monetize social and environmental benefits. Environmental benefits are valued differently by different stakeholders, which challenges the findings of the analysis. For instance, greenhouse gas (GHG) mitigation, which is a global ecosystem service, may be prioritized over reducing soil erosion which is a local benefit. Applying a discount rate is also an inherently subjective decision, but it is important for prioritizing near-term benefits versus long-term benefits. Additionally, the value of some environmental benefits, such as supporting biodiversity, are often excluded because monetizing them is challenging (Gromko et al., 2019). However, it is still possible to include some non-monetized values such as biodiversity in the decision-making.

Third, during CBA of land restoration, it is difficult to monetize social or political considerations. Restoration options selected during CBA should produce maximum benefits for all, but this is usually not the case. Due to political reasons, benefits to one group may be valued more than the benefits of another group and as such may not be included in the CBA (Gromko et al., 2019). Data collection to be used for CBA of restoration can be time-consuming and expensive since the impacts of restoration transitions are felt over long periods of time. Step 4 of the cost-benefit framework (as outlined in section 2.2), is to quantify all the impacts for each land use (degraded and restored) for the relevant time horizon of the project (Verdone, 2015). Predictions about the levels of inputs (i.e., costs) and the production of ecosystem services must be made for each year and each land use in a restoration transition. This can be the most challenging aspect of CBA because there is not always a complete scientific understanding of how complex natural systems work, especially when significant changes to their structure are made.

Uncertainties in the entire CBA process such as fluctuating prices, discount rates and unseen events within the restoration lifetime can affect the estimated results, mainly when the CBA is conducted ex-ante. Hence, after conducting a CBA, it is necessary to conduct a sensitivity analysis by altering various parameters of the estimation, such as the discount rate or prices. Alternatively, one may conduct a Monte Carlo simulation. A Monte Carlo simulation is similar to sensitivity analysis in that it demonstrates how a project's profitability varies. However, instead of altering one input variable and analysing how that changes in that variable affects the project viability, a Monte Carlo simulation attempts to model uncertainty across multiple input assumptions. The model is run thousands of times to understand different possible outcomes and the likelihood of them occurring (Gromko et al., 2019). The Monte Carlo simulation is more rigorous and robust compared to the regular sensitivity analysis.

2.5 Benefits and costs of landscape restoration

2.5.1 Cost of restoration

The total cost of these inputs depends on how degraded a site is and how difficult it is to restore. Additionally, costs vary according to geography, degradation category, the objectives and contexts of specific restoration activities, and the types of restoration methods that are used (Sukhdev, 2008). There are three investment phases involved in FLR. 1) Phase 1 is the initial readiness or up-front investment. During this phase, investments flow towards designing projects, planning, stakeholder engagement and participation, developing safeguards and capacity building. 2) Phase 2 is the investment for actual implementation. This phase involves policy reforms, implementation of the restoration of degraded lands, educational activities, land-use zoning and strengthening of capacities. 3) Phase 3 focuses on sustained financing for landscape ecosystem services and product services for self-sustaining funding of the project's long-term running costs (FAO and UNCCD, 2015; Gichuki et al., 2019)

Restoration costs can thus be categorized into:

1) Implementation costs (usually very high); these include costs of raw materials such as tree seedling, fencing, labour and transport costs, among others. It also includes costs incurred in capacity building and training of local stakeholders. They mainly comprise direct costs incurred in the project. Land users usually incur these costs, but they can also be covered by the project.
2) Opportunity cost: this represents the cost of foregone opportunities; they comprise the tangible goods and services that were foregone to make restoration possible. To capture the opportunity cost, it is necessary to conduct a baseline study prior to project implementation.
3) Transaction costs: these represent the costs incurred by landowners and implementing agencies when identifying viable land that can be restored and negotiating over terms that would ensure that restoration meets both local and national priorities (Verdone, 2015). These may include monitoring costs, as well.

2.5.2 Benefits accruing from restoration

The benefits to be captured within restoration ought to include both use and non-use values, as well as private and public benefits arising from the restoration, i.e., the total economic value of the restoration. Any analysis that measures the total economic value (TEV) of an investment attempts to estimate and monetize all economic impacts of the investment. TEV recognizes that benefits and costs radiate far beyond the landowner or investor to the global effects. Figure 1, adapted from Pascual et al. (2010), outlines the various benefits that ought to be captured while assessing the TEV of a project. This approach accounts for both use and non-use benefits values.

The use values are categorized into:

a) Direct use values: These relate to the benefits obtained from the direct use of an ecosystem. Most of the direct products have market values such as timber, poles, charcoal, gum arabica, medicine, as well as other non-timber forest products (NTFPs) such as wild fruits, honey, fodder, crop harvests, recreation value and others. They are the most straightforward benefit category to capture and account for since the data on quantities and value is available for most of the restoration projects.
b) Indirect use values: These are usually associated with regulating services. They include carbon sequestration, water treatment and regulation, soil erosion control, pollination, and so on.
c) Option values: These include valuing ES for the option of future use such as medicinal purposes.

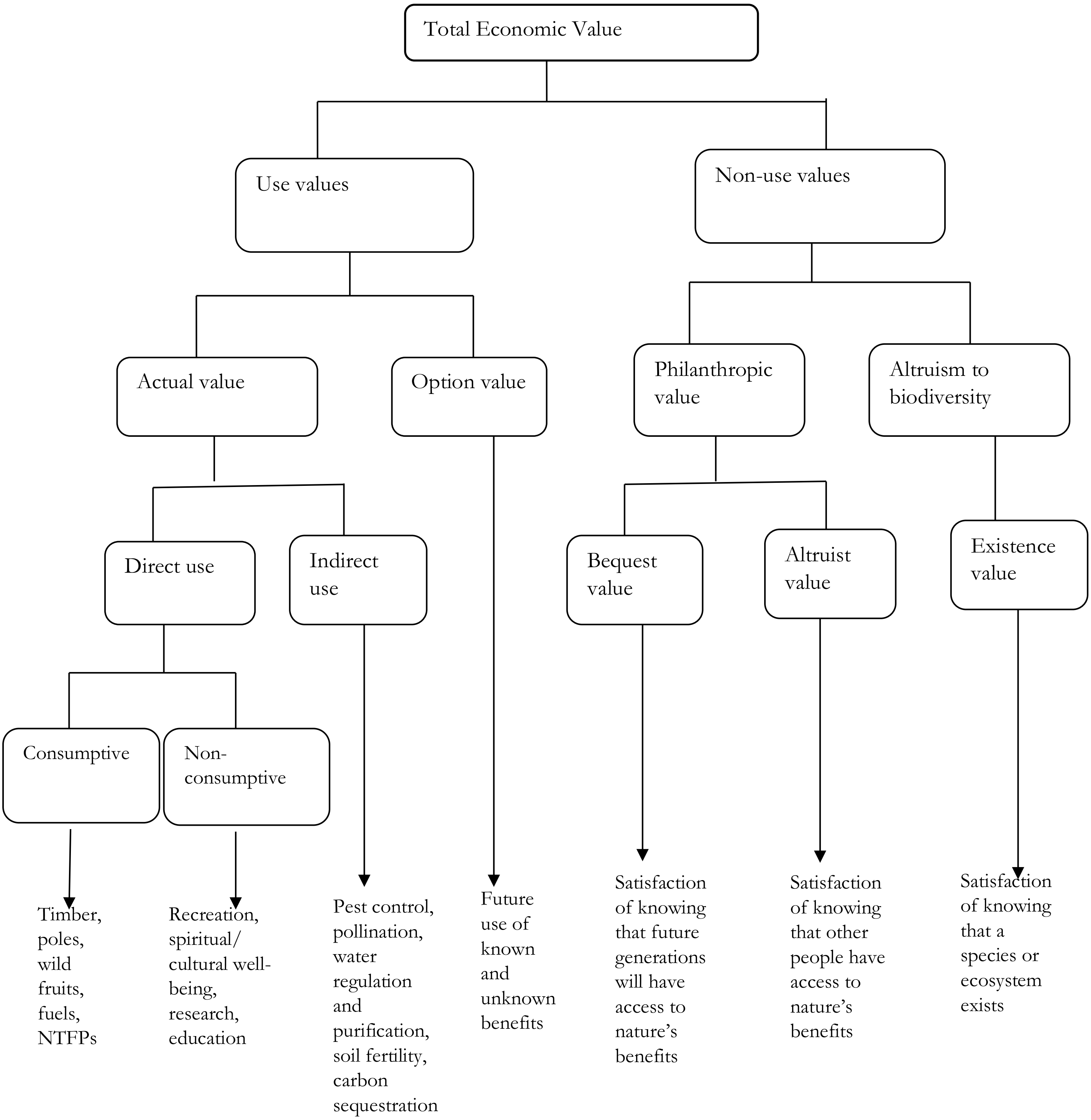
Non-use values, on the other hand, are categorized as follows:

a) Bequest value: This captures the value arising from the satisfaction of knowing that future generations will access nature's benefits. The value is concerned with intergenerational equity.
b) Altruist value: This value involves intragenerational equity, i.e., the satisfaction of knowing that other people can also access nature's benefits.
c) Existence value: This value is derived from the satisfaction of knowing that a certain species exists. For example, indigenous trees, endangered species and medicinal trees.

Based on the criteria for identifying and valuing these benefits and the role they play, The Economics of Ecosystems and Biodiversity (TEEB) classifies these benefits into:

a) Provisioning services: These include direct benefits such as timber and non-timber forest products. Examples – timber, fuel, fibre, fisheries, wild animals, medicinal plants.
b) Regulating services: These include services such as carbon sequestration, water flow regulation, air quality, erosion regulation, pest and disease control, pollination, maintaining genetic diversity, flood regulation.
c) Cultural services: These include recreational use, spiritual, educational and aesthetic value.
d) Habitat.

Ideally, for the CBA to be comprehensive, it ought to capture all the benefits' components. Direct use values are relatively easy to identify and value since they are tangible and usually have market values. On the other hand, indirect use and non-use value pose a challenge and the valuation methods employed are often time- and resource-intensive. Several studies, such as Gundimeda et al. (2018) and Chiputwa et al. (2020), detail how to adequately value these benefits through a wide range of valuation methods including: production methods, choice experiments, contingent valuation methods (CVM), hedonic pricing, travel cost methods, cost-based approaches, benefit transfer and mean-variance analysis.



Adapted from Pascual et al. (2010)

Figure 1: Total Economic value for assessing total benefits

We conducted a systematic review of cost-benefit analysis for landscape restoration by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[5] guidelines. Figure 2 presents the process of the systematic review followed. The first step was a keyword search using the "publish or perish[6] software" through Google Scholar. We searched for a combination of three phrases 1) *"Cost-benefit analysis" and "Landscape restoration*" 2) *"Economics" and "Landscape restoration"* 3) *"Cost-benefit analysis" and "Land restoration"*. The search for *"Cost-benefit analysis" and "Landscape restoration"* generated 522 studies, while the search for *"Economics" and "Landscape restoration"* generated 922 studies and that of *"Cost-benefit analysis" and "Land restoration"* generated 612 studies.

For step two, we filtered down the outputs by titles and abstracts and ended up with 82 relevant publications. For the 102 publications, we read through the full text. We found 31 publications that were either entirely focused on CBA of landscape restoration or had a component of CBA of landscape restoration. The 31 publications are the ones that have been considered in the review, and a summary of these studies is presented in the appendix (Table A1). The summary is based on restoration options/strategies, country of focus, data sources, the time considered in the CBA analysis, benefits and costs components, sensitivity analysis conducted and the results of the CBA.

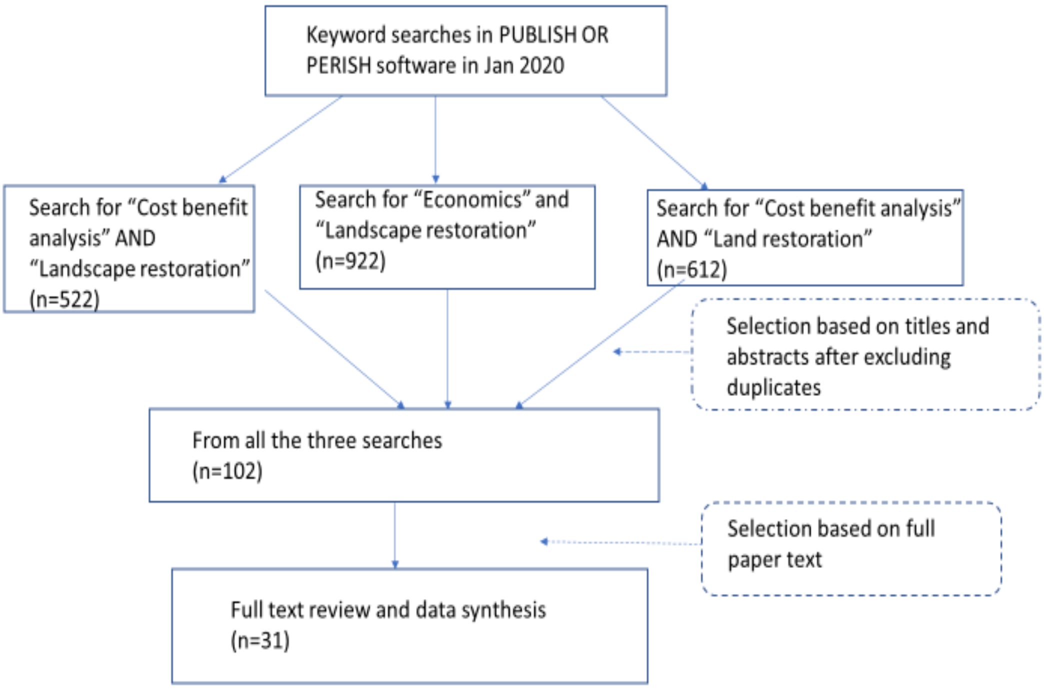


Figure 2: Systematic review of CBA of the restoration process

[5] http://www.prisma-statement.org/
[6] https://harzing.com/resources/publish-or-perish/windows

4.0 Results and Discussion

From the systematic review process explained in the methodology section, 31 publications of CBA on land restoration were identified. In this section, these publications are discussed based on several attributes.

4.1 Country of focus and study year

The 31 studies under review were conducted in about 20 countries distributed across five regions; Africa (10), Europe (2), North America (2), South America (3), Asia & Middle East (3). Almost all the 31 studies reviewed were conducted in a single country, and only five focused on multiple countries. Of the five, three studies focused on a global perspective (De Groot et al., 2013; Elmqvist et al., 2015; FAO and UNCCD, 2015); while one focused on multiple African countries[7] (ELD Initiative and UNEP, 2015) and one focused on several countries in Latin America[8] (Birch et al., 2010). As shown in Figure 3, countries which have had the most CBA studies conducted over the years had, on average, three studies and include South Africa, Brazil and Tanzania. Ethiopia, Kenya and Vietnam have had two CBA studies conducted in each of them.

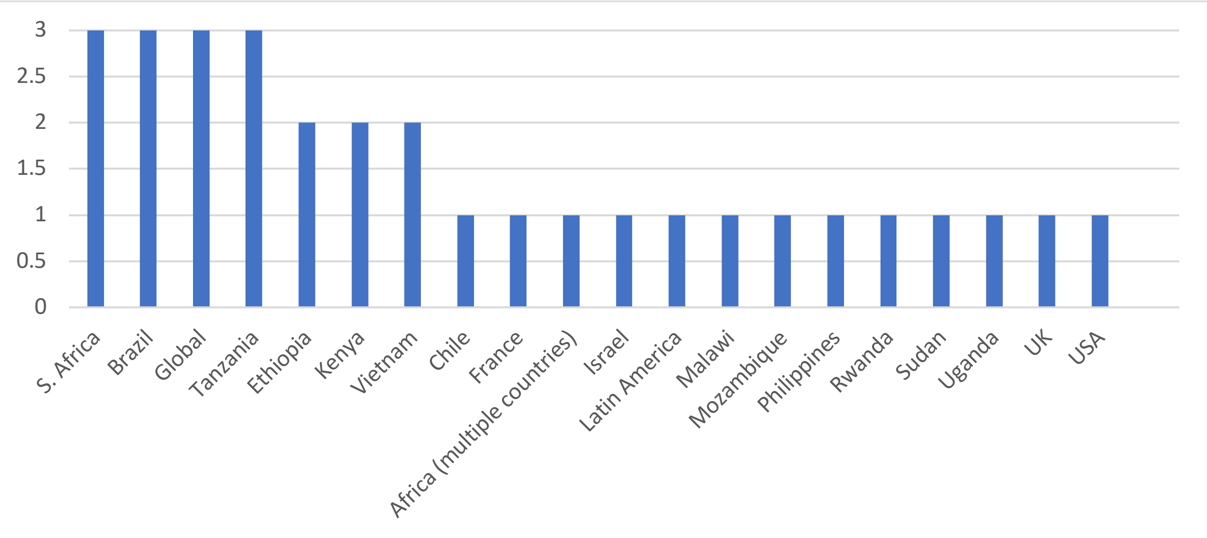


Figure 3: Distribution of CBA studies across various countries

Figure 4 presents a trend of the year studies on restoration under review were conducted. The oldest study reviewed was conducted in 1997 in France and focused on landscape restoration using hedgerows (Bonnieux and Le Goffe, 1997). The most recent studies were conducted in Kenya by Cheboiwo et al. (2019) and in Brazil by Gasparinetti et al. (2019).

[7] Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Côte D'Ivoire, Djibouti, DR Congo, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, UR of Tanzania, Zambia, Zimbabwe.

[8] The focus Latin America countries include; Mexico, Argentina and Chile.

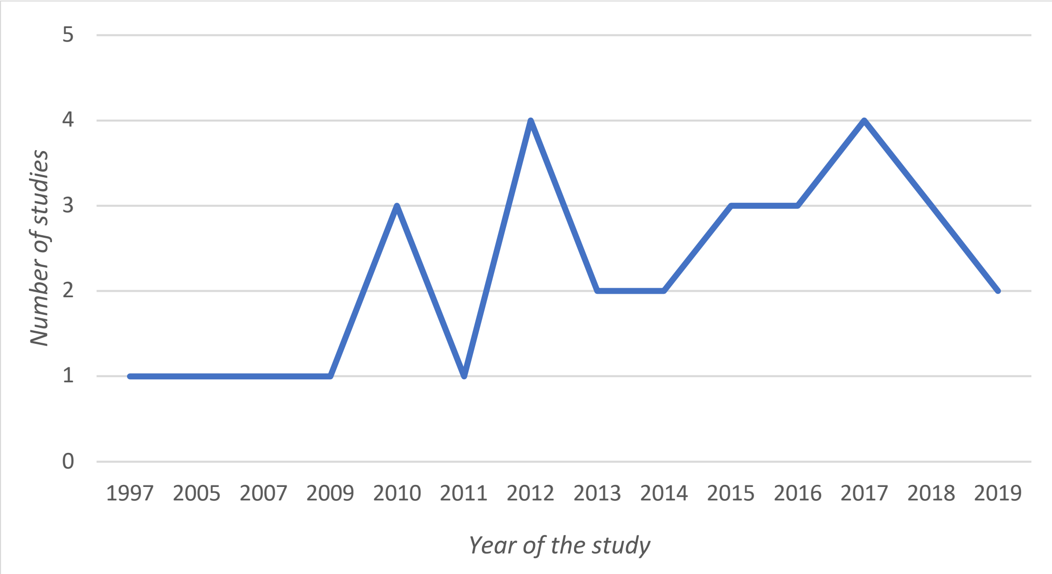


Figure 4: Year CBA studies were conducted

4.2 Landscape restoration options

As shown in Table 2, the CBA studies reviewed were conducted for different types of restoration options/strategies including; reforestation and afforestation, agroforestry, biofuel agroforestry, participatory forest management, woodlot establishment, sustainable land management (SLM) practices, natural regeneration, assisted natural regeneration, mangrove restoration, clearing of invasive alien species, urban area restoration and buffer area restoration.

Some studies focused on only one type of restoration, while others conducted a comparison of different restoration options depending on the land use type. One of the most comprehensive CBA studies reviewed was conducted in Kenya by Cheboiwo et al. (2019) and compared returns for several landscape restoration strategies including; afforestation or reforestation of degraded natural forests, rehabilitation of degraded natural forests, agroforestry in cropland, commercial tree and bamboo growing on potentially marginal cropland and un-stocked forest plantation forests, tree-based buffer zones along water bodies and wetlands, tree-based buffer zones along roads and restoration of degraded rangelands.

Overall, the most popular landscape restoration options for which CBA studies were conducted include; reforestation and afforestation (8), agroforestry (7), farmer-managed natural regeneration/assisted natural regeneration (5), soil and water conservation practices (5) and establishment of woodlots (4). Further still, Verdone and Seidl (2017) assessed the net present value of the Bonn Challenge, which is a global effort to restore 350 million hectares of degraded forest landscape.

Table 2: Land restoration options considered in the CBA studies reviewed

Land restoration options	No. of studies	Countries of focus
Reforestation and afforestation	8	Brazil, Chile, Ethiopia, Kenya, Uganda, USA, Chile, Tanzania
Agroforestry	7	Brazil, Ethiopia, Kenya, Sudan, Tanzania, Uganda, Malawi
Participatory forest management/FMNR/ANR	5	Brazil, Ethiopia, Malawi, Vietnam, Tanzania
Soil and water conservation measures and SLM practices, e.g., bunds, terracing, zero tillage,	5	Ethiopia, Kenya, Malawi, Vietnam, multiple countries in Africa
Establishment of woodlots	4	Ethiopia, Malawi, Uganda, Tanzania, Rwanda
Mangrove restoration (protective and planting	3	Mozambique, Philippines, Vietnam
Natural regeneration	2	Uganda, Rwanda
River restoration/habitat restoration for river catchment	2	Israel, UK
Dryland forest restoration	2	Latin America, Chile
Alien vegetation clearing for water yield and tourism	2	South Africa (2)
Biofuels agroforestry or biofuel for energy thus reducing deforestation	1	Tanzania,
Landscape restoration using hedgerows	1	France
Urban area restoration (Green and blue infrastructure in urban areas	1	Multiple countries
Tree-based buffer zones along water bodies and wetlands	1	Kenya
Tree-based buffer zones along roads and riparian land	1	Kenya
Restoration of degraded rangelands	1	Kenya
Subtropical Thicket Restoration	1	South Africa

Figure 5 presents reported NPV (positive or negative) by various CBA studies for different landscape restoration options. For some of the restoration options, all studies conducted reported positive NPV; agroforestry (8 studies), soil and water conservation (5), mangrove restoration (3) and alien vegetation clearing (3). However, for some of the restoration strategies, certain studies reported negative NPV; for reforestation and afforestation, the number of studies that reported positive NPV (4) was equal to those that reported negative NPV (4). For other restoration options – FMNR/ANR and woodlot establishment – the number of studies that reported positive NPV was higher than those which reported negative NPV.

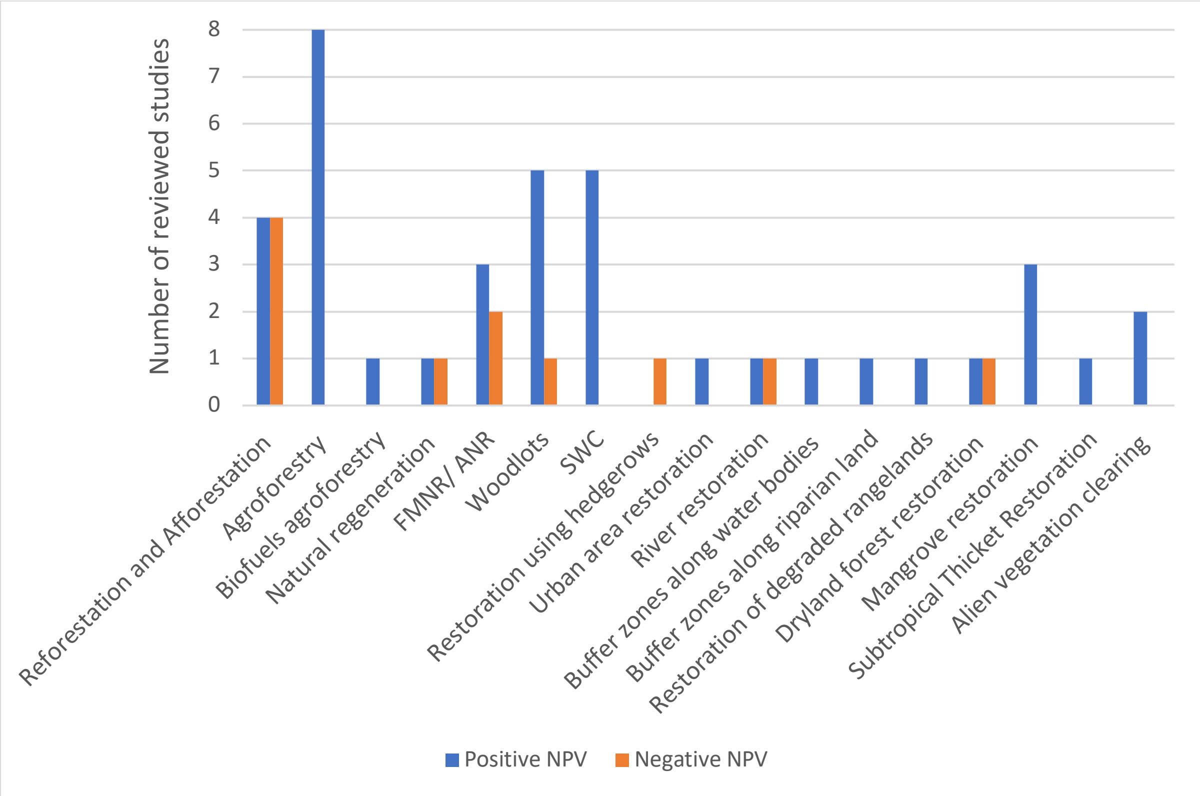


Figure 5: Reported NPV for the various landscape restoration type by the various assessed studies

4.3 Age of restoration in the CBA studies

Figure 6 illustrates the time in years for which different studies under review considered. A higher number of CBA studies, (8) covered restoration benefits and costs for 16-20 years. Another six studies covered 21-25 years. The maximum duration that was considered was 100 years by two studies; Narayan et al. (2017) in Mozambique and Bonnieux and Le Goffe (1997) in France. A further three CBA studies (Chadourne et al., 2012; Mills et al., 2007; Newton et al., 2012) covered restoration benefits and costs for 50 years.

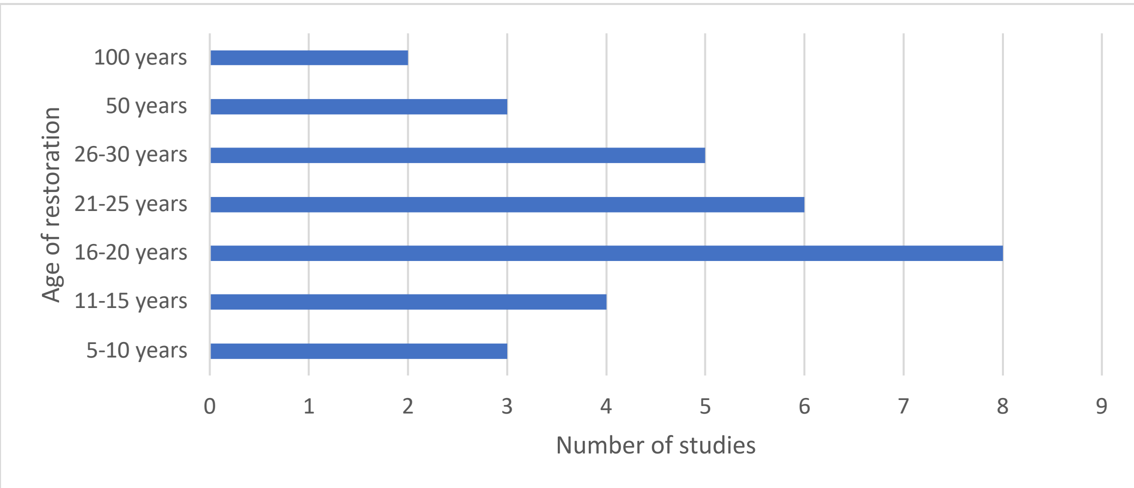


Figure 6: Restoration project timeline considered in the CBA

4.4 Data source

The CBA studies reviewed obtained data from different sources; 12 studies used primary data, 11 applied secondary data, and the remaining eight used both primary and secondary data. For primary data, various studies applied different data collection methods and techniques, as indicated in Figure 7. Approximately seven studies used expert discussions, key informant interviews (KIIs) or focus group discussions (FGDs). Others employed other data collection techniques including; surveys, reviewing budgets, spatial analyses and field observations.

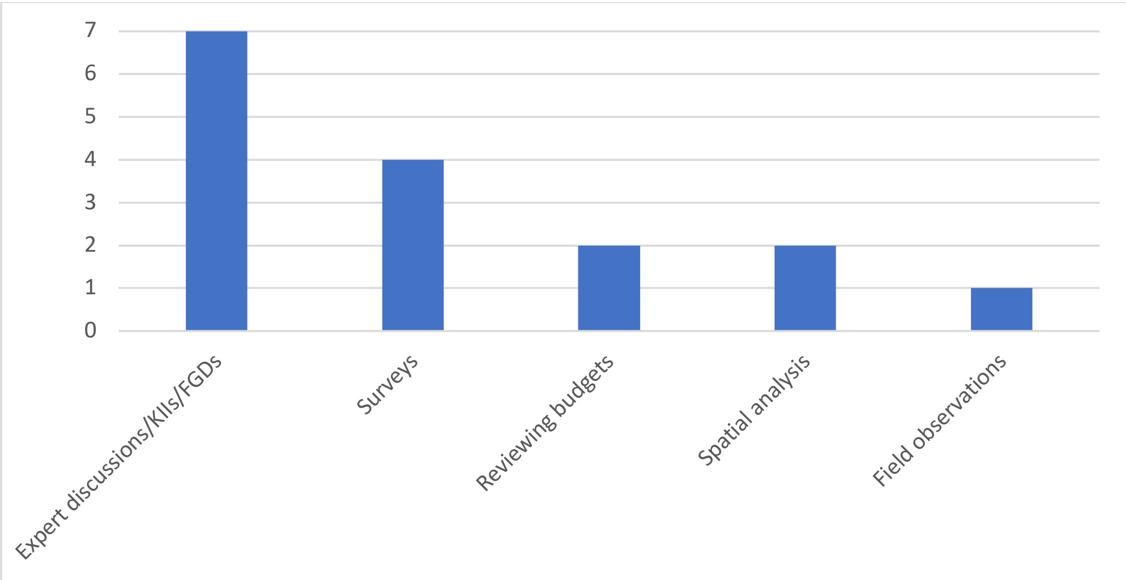


Figure 6: Primary data collection methods employed in the restoration CBA studies

For those studies that considered indirect use and/or non-use benefits in their analyses, different approaches were applied in valuing these benefits since most of them do not have a market value. Three studies applied the contingent valuation method, and at least one used either hedonic analysis, travel cost method or benefit transfer method.

4.5 Benefits and cost components in the CBA studies

4.5.1 Benefits

Figure 8 presents the proportion of studies that considered different benefits categories; the majority of the studies accounted for the use values only (either direct use, indirect use or both), while only around 16% accounted for the total economic value of the project (both use and non-use values). About half of the studies accounted for both direct and indirect use values. Of these, the indirect use benefit that was mostly considered in these restoration studies was carbon sequestration. Other indirect use benefits that were accounted for include; erosion control, stormwater control, air regulation, temperature regulation, recreational value, avoided nutrient loss, nitrogen fixation, soil fertility improvement and aquifer recharge. Non-use values that the reviewed studies accounted for include; aesthetic value, bequest (inheritance) value and existence value.

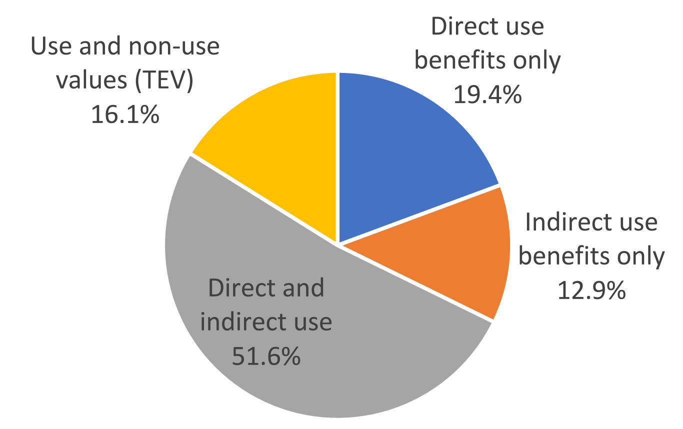


Figure 7: Benefit categories considered in the CBA studies reviewed (n=31)

These studies applied different valuation methods to assess the respective benefits (see Table 3). A more detailed explanation of these benefits by the specific study is provided in the Appendix Table A1. Provisioning services were considered in almost all the studies. They were commonly assessed by collecting primary/secondary data on the quantities of these goods and valuing them at the current market price. Carbon sequestration was valued by either spatial analysis (e.g., Birch et al., 2010; Pistorius et al., 2017), or sourcing the quantities from secondary data and valuing them using the market price of carbon. Contingent valuation method was applied by several studies in valuing benefits including; air pollution and regulation[9], public benefits[10], cultural, aesthetic and recreation values[11] and inheritance and bequest values[12].

Benefit transfer method was frequently applied in valuing many indirect use benefits such as air pollution and regulation, biodiversity improvement, soil fertility, soil erosion control, temperature control, positive health effects, recreation and stormwater control. A comprehensive example of the use of benefit transfer is in De Groot et al. (2013), where they used data collected from 94 studies. From these, they created a database of benefits and costs which they used in conducting CBA for seven biomes.

In addition, the FAO and UNCCD (2015) used secondary data and the comprehensive TEEB database due to Van der Ploeg and De Groot (2010) in valuing benefits while assessing the CBA of FLR within the Bonn Challenge within six different biomes. In the absence of site-specific valuation information, benefit transfer is an alternative to estimating non-existing values. It adapts existing valuation information to a new context (location or time) and is principally useful during collection of primary data where there are budget and time

[9] Schiappacasse et al. (2012)
[10] Bonnieux and Le Goffe (1997)
[11] Newton et al. (2012)
[12] Becker et al. (2018)

constraints (Chiputwa et al., 2020). However, there is a need to ensure that the ecological conditions are the same, otherwise the value could either be over- or under-stated.

Hedonic pricing method was the least frequently applied valuation method; only one study used the approach in valuing stormwater control and air pollution control (Chadourne et al., 2012). The study employed the hedonic models by controlling for the price of housing in different locations. The reason this method is rarely applied is because the data required can be quite intensive. Similarly, it works well if markets can pick up quality differentials, which may not be the case for agricultural and forest land, due to the non-observability of some attributes (Gundimeda et al., 2018). Further still, Cheboiwo et al. (2019) applied the replacement cost approach to value soil fertility and the avoided loss approach to value soil erosion control.

Table 3: Valuation methods applied across various benefits

Benefits	**Valuation methods**
Timber, wood fuel, NTFPs, livestock, yield benefits	• Primary data valued at existing market price • Expert opinion
Tourism	• Value of tickets paid at the entrance • Travel cost method
Carbon sequestration	• Spatial analysis • Secondary data valued at the market price of carbon
Public benefits	• Contingent valuation methods, i.e., assessing willingness to pay for these benefits
Air pollution and air regulation	• Hedonic method • Contingent valuation method • Benefit transfer
Stormwater control/reduction	• Hedonic methods • Benefit transfer
Increased soil fertility	• Replacement cost method • Benefit transfer
Soil erosion control	• Avoided cost • Benefit transfer
Temperature regulation	• Benefit transfer
Cultural, aesthetic and recreation	• Contingent valuation method, assessing willingness to pay
Positive health effects	• Benefit transfer
Biodiversity recovery	• Secondary data with simulations • Benefit transfer
Inheritance and bequest values	• Contingent valuation methods
Total economic value for global studies	• Secondary data and benefit transfer particularly from TEEB valuation database

4.5.2 Costs

Three cost categories were considered in the studies reviewed as presented in Figure 9; implementation costs, maintenance costs (mostly annual costs of maintaining the restoration infrastructure) and opportunity costs (cost of foregone opportunities). All the CBA studies reviewed considered implementation cost since it is the most direct cost in restoration and is easily captured. Approximately 25% considered only implementation costs, while a further 45% covered both implementation and maintenance costs—only 16% of the reviewed studies included all the three cost categories. Implementation and maintenance costs were mostly sourced from the costs incurred in the projects. Implementation costs included investment costs such as seedlings, materials and other inputs labour and training costs, among others. Maintenance costs include monitoring and transaction costs. For opportunity cost, on the other hand, the studies had to conduct baseline assessments to ascertain the value of foregone opportunities. For example, Wiskerke et al. (2010), assessed the baseline situation of agriculture and grazing, which was translated into the opportunity cost of the land.

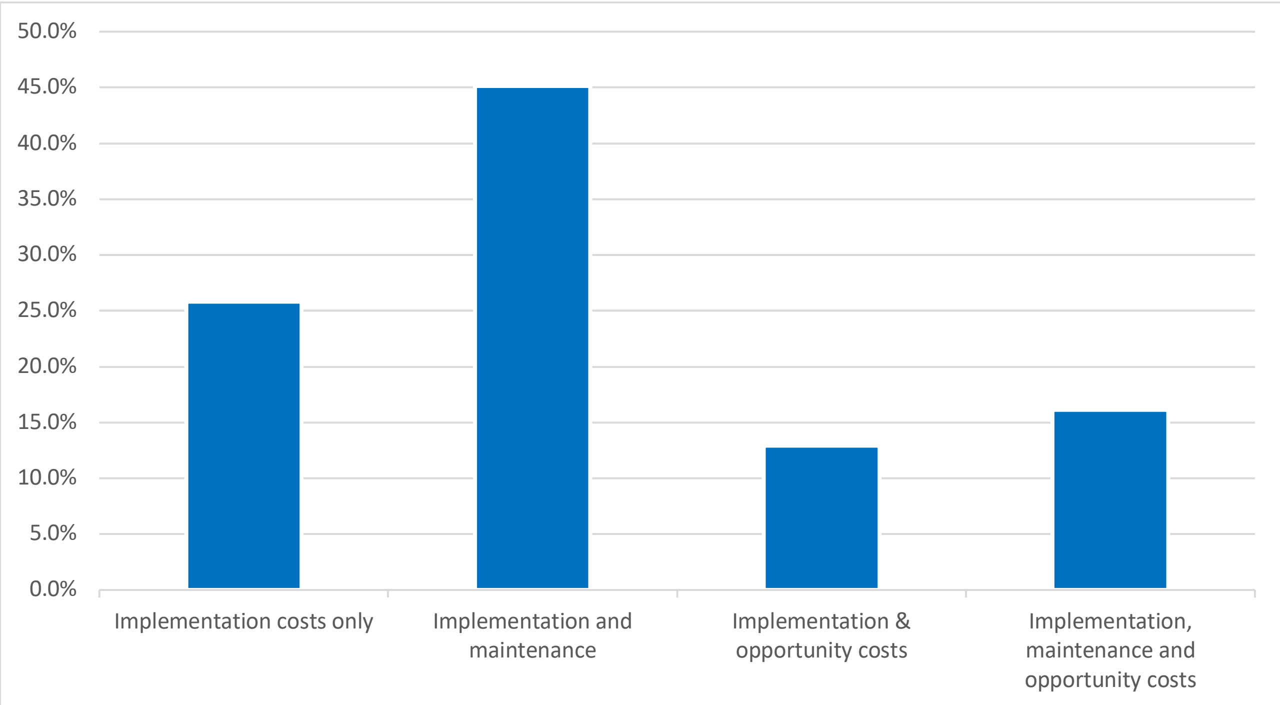


Figure 8: Cost categories considered in CBA received (n=31)

4.6 Sensitivity analysis

Sensitivity analysis is normally conducted to assess how the CBA results differ depending on various parameters. It recognizes that different variables such as prices, discount rates and cost parameters are subject to change in the course of the project. This analysis can be conducted either by varying one or more parameters, mostly the discount rate, or by conducting a more rigorous method such as the Monte Carlo simulation.

Figure 10 presents the proportion of studies under review that conducted a sensitivity analysis to test the validity of their results. Of the 31 studies reviewed, none applied the rigorous Monte Carlo simulation. Approximately 23% did not conduct any form of sensitivity analysis. Majority of the studies (about 35%) conducted the analysis by varying the discount rates only. Additionally, a further 19% varied the discount rates and other parameters such as carbon prices, product prices, maintenance costs, and so on. About 13% tested the validity of the CBA results by varying the best- and worst-case scenarios by assuming a very optimistic scenario where most of the assumptions hold and a very pessimistic scenario where most of the assumptions do not hold. Still, 10% of the reviewed studies only varied other parameters without varying the discount rate.

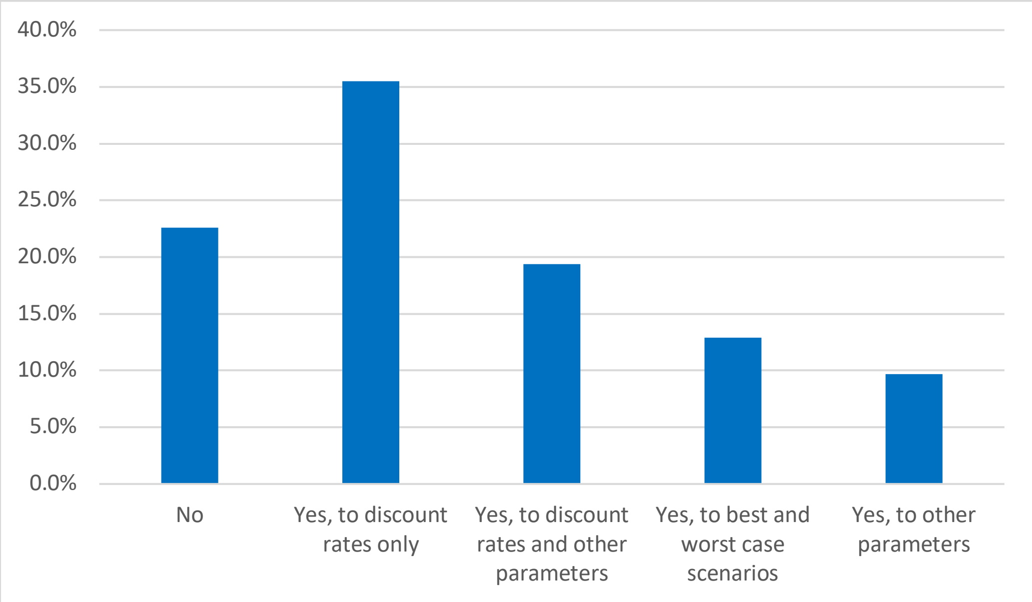


Figure 9: Sensitivity analysis across the CBA studies under review (n=31)

5.0 Conclusion

From the exploratory review and review of existing studies on CBA of restoration, gaps that future studies ought to consider were highlighted. A significant proportion of existing CBA studies do not account for indirect use benefits, and an even more substantial proportion do not account for non-use benefits. This is mostly because most of these benefits are "invisible" and do not have a market value, thus making valuing them quite challenging. Some of the studies that included the indirect and non-use values applied various evaluation methods including; benefit transfer, contingent valuation method, travel cost method, hedonic pricing models, replacement cost, avoided loss and spatial analysis. Benefit transfer and contingent valuation methods were more frequently applied compared to the other methods. This is probably because these methods can be applied in the valuation of almost all the benefits such as air pollution control, biodiversity, inheritance and bequest value, cultural and aesthetic values, and so on. Similarly, benefit transfer is generally cost-effective and is commonly applied when there is limited budgetary allocation. On the other hand, some of the other methods (e.g., hedonic models, avoided loss, replacement costs) are data-intensive and, cannot be universally applied for most of the benefits. Hence there is need to understand the methods that should be used to reasonably value specific benefits arising from the project depending on nature of the benefit/ecosystem services data availability, time and cost constraint, and so on.

In addition, some of these benefits are public benefits attributable to other stakeholders beyond those directly targeted by the restoration projects. A comprehensive economic CBA ought to account for all these benefits. Otherwise, the estimated NPVs for these restoration projects are undervalued. Hence to present a true picture of the profitability of restoration projects, future CBA studies should aim to capture all the benefits arising from restoration projects – use and non-use benefits, as well as private and public benefits. This is particularly useful for large-scale restoration projects where the benefits accrue to the broader public beyond the targeted stakeholders. Verdone and Seidl (2017) also found that when the value of public goods and services are accounted for in the cost-benefit analysis, the benefits of large-scale restoration outweigh costs, and targets like the Bonn Challenge can be met efficiently.

Similarly, most of the studies do not account for all the costs associated with restoration. All the reviewed studies accounted for implementation costs, but relatively few covered all the cost categories (16%). The least accounted for cost category is the opportunity cost; probably because it is often difficult to estimate since it is not a direct cost. Estimating the opportunity cost requires a baseline assessment to identify foregone uses of the land. Most of the studies do not conduct baseline assessments, thus making it challenging to provide an estimate of the opportunity cost. In addition, for some land uses the opportunity cost may be negligible, especially if the land is highly degraded.

Moreover, there is a need to include maintenance and monitoring costs in accounting for the total economic costs. Most restoration projects fail to account for maintenance and monitoring costs since they view restoration as a one-time cost activity as opposed to a continuous activity—for example, tree-planting as opposed to tree-growing (Duguma et al., 2020). Tree-planting is a one-time cost activity where the only significant cost will be the implementation cost. On the other hand, tree-growing is a continuous activity, implying that maintenance and monitoring costs are significant and accountable, as well. Hence, all the three cost categories ought to be accounted for, for a cost-benefit analysis to reflect the actual economic viability of a restoration project.

Closely related, lack of reliable data owing to poor data-keeping during the restoration period also affects the CBA results. It takes time to realize the actual profitability of these restoration investments since returns in landscape restoration projects are not immediate. For example, in the studies reviewed, restoration age considered was up to 100 years for some projects, with the minimum being seven years. This requires data over several years, and most projects do not keep a record of this data. Hence, even for ex-post CBA evaluations, a lot of predictions and assumptions are involved in data generation. Thus, there is need to adopt standardized methods of data prediction if the results are to be comparable across different restoration projects in deciding the allocation of funds. Similarly, the FAO 'The Economics of Ecosystem

Restoration' (TEER), points to the need for a comprehensive tool on costs and benefits of Ecosystem Restoration (and FLR) interventions[13]. In an ongoing project, TEER aims to "offer a reference point for the estimation of costs and benefits of future ER projects in all major biomes, based on information from comparable projects on which data are collected through a standardized framework"[13].

Sensitivity analysis is a vital stage in the CBA process since it provides a robustness check for the results. While conducting sensitivity analysis, almost all the existing studies reviewed conducted a direct sensitivity analysis by varying only one or just a few variables, mostly discount rate or carbon prices. None of the studies applied a more rigorous sensitivity test, such as the Monte Carlo simulation approach. For more robust results, future CBA on restoration should consider more rigorous approaches for sensitivity analysis, such as the Monte Carlo simulation.

[13] https://www.vi-med.forestweek.org/sites/default/files/presentations/docs/c5-teer-garavaglia.pdf

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Appendix

Table A1: A summary of studies conducted to assess CBA of landscape restoration following a systematic review

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
1	Baig et al. (2016)	Philippines	Ecosystem-based adaptation using mangrove protection and planting	Secondary data	20	Total economic values (direct use, non-direct use values and non-use values	Implementation costs	Positive	Yes, to discount rate	Communal
2	Becker et al. (2018)	Israel	Full and partial river restoration	Primary data through CVM and travel cost methods	varies	Total economic values; Use values (direct and optional use values) and non-use values (inheritance (bequest) and existence values)	Restoration costs (fixed value and the yearly value of maintenance)	Positive	No	Communal
3	Birch et al. (2010)	Latin America	Dryland forest restoration	Primary data through spatial analysis	20	Carbon sequestration, NTFPs, timber, tourism and livestock products (benefit between restoration and BAU scenario)	Implementation costs (fencing and fire suppression), opportunity costs (cost foregone from livestock production from forest expansion	Positive	Yes, to discount rates and market price of carbon	Private and communal
4	Bonnieux and Le Goffe (1997)	France	Landscape restoration using hedgerows	WTP (to assess public benefits	100	Firewood, timber and public benefits	Planting and regenerating costs, maintenance costs	Negative	No	Communal

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
5	Chadourne et al. (2012)	USA (Tennessee)	Forest landscape restoration	Primary data- hedonic models were used to	50	Indirect use values (air pollution mitigation and stormwater control)	Explicit costs (land acquisition, labour, seedlings, materials) and amenity value	Positive	No	Private and communal
6	De Groot et al. (2013)	Global	Restoration of 9 different biomes	Secondary data Reviews of 94 studies	20	Total Economic value of all services	Implementation costs, maintenance costs	Positive for the various restoration types considered	Yes, to discount rate and to worst-case and best-case scenarios	Communal
7	ELD Initiative and UNEP (2015)	Africa (Djibouti,	Sustainable land management against soil erosion	Secondary data mostly from FAO and world bank data	15	Avoided crop damages from erosion control	SLM establishment cost and SLM maintenance costs	Positive	Yes, by varying discount rates, prices of cereals, capital and maintenance costs.	Private and communal
8	Elmqvist et al. (2015)	Global	Urban areas restoration (Green and blue infrastructure in urban areas)	Secondary data (review)- Benefit transfer	20	Ecosystem services (pollution and air regulation, carbon sequestration, stormwater reduction, temperature	Costs for planning, preparation, modest soil restoration, plant propagation, and	Positive	Yes, to discount rates and max/min benefits and costs	Communal

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
						regulation, recreation, positive health effects)	planting both for grasslands and woodlands			
9	FAO and Global Mechanism of the UNCCD (2015)	Global	CBA of FLR within the Bonn Challenge within six different biomes	Primary and secondary data from TEEB	varies	Total Economic value both direct and indirect benefits	Bonn Challenge cost of restoration	Positive	No	Private and communal
10	Gasparinetti et al. (2019)	Brazil (South Amazon)	FLR through agroforestry with cocoa, coffee and Guarana	Primary data	30	Direct outputs and ecosystem services	Maintenance, fencing, labour costs, machine costs	Positive	Yes, to discount rates	Private
11	Hofer et al. 2010	Brazil (Amazon)	Reforestation (land use from pastures to forest for carbon sequestration (carbon for credits)	Secondary data	20	Carbon sequestration	Opportunity, implementation, and transaction costs	Negative	Yes, to different carbon prices	Communal
12	Narayan et al. 2017	Mozambique	Mangrove restoration to shelter against storms and flooding	Secondary data from an adaptation project conducted in 2013	100	Reduction in storm damages to houses, fish production, aquaculture, apiculture, carbon sequestered by growing mangroves	Costs of buying the seedlings; labour for planting, maintenance, and support staff; and hydrological restoration	Positive	Yes, to different carbon prices and discount rates	Private and communal

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
13	Newton et al. (2012)	UK	Habitat restoration for river catchment	Primary data	10 and 50 years	Marginal value of benefits- carbon, timber, crops, livestock and recreational, aesthetic and cultural values	Initial capital investment and annual maintenance costs	Negative	Yes, to different carbon prices and discount rates	Communal
14	Pistorius et al. (2017)	Ethiopia	FLR-1) Afforestation/reforestation 2) participatory forest management 3) sustainable woodland management 4) restoration of afro-alpine or sub-afro-alpine 5) establishment of woodlots	Primary data- spatial analysis and expert opinion	20	Provisioning services (timber & NTFPs), Carbon sequestration	Investment costs and labour costs	Positive except for the afro-alpine slope restoration	No	Communal
15	Mills et al. (2007)	South Africa	Restoration of natural capital through subtropical thicket restoration	Secondary data with simulations	50	Livestock and game production, harvesting plant products (assuming natural recovery of biodiversity), and carbon sequestration	Transaction costs (including costs of verification of carbon stocks), labour costs, opportunity costs	Positive	Yes, to various parameters including biomass growth rate,	Communal
16	Holmes et al. (2007)	South Africa	Restoring natural capital following alien plant invasions in fynbos ecosystems	Projections from secondary data	30	Direct and indirect use benefits	Clearing costs, installation costs	Positive	Yes, to discount rates	Communal

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
17	Rizetti et al. (2018)	Vietnam	FLR through ANR, extended acacia rotation, native species rotation, SWC	Projections from secondary data	23, 30, 2	Crop income, income from timber	Labour costs, seedling cost	Positive	No	Private and communal
18	Schiappacasse et al. (2012)	Chile	Dryland forest restoration thru reforestation using native trees	Primary data using contingent valuation method	25	WTP for forest restoration for the entire pollution of the city	Implementation costs, operating costs,	Negative	Yes, to discount rate	Communal
19	Currie et al. (2009)	South Africa	Alien vegetation clearing for water yield and tourism	Primary data and projections	15	Water and tourism benefits (tourism benefits involved revenue from the sale of tickets)	Costs of alien invasive plant removal, gully-erosion repair and reseeding with indigenous plants	Positive	Yes, to discount rates and with realistic and pessimistic scenarios	Communal
20	Silva and Nunes (2017)	Brazil Amazon	Forest restoration through sustainable forest management (legal logging) and agroforestry	Secondary	11	Timber from logging, financial benefits of AFS (timber and NTFPs)	Implementation costs, transaction costs, opportunity costs (loss from agriculture and livestock)	Negative	Yes, to discount rates and different scenarios	Communal
21	Tuan and Tinh (2013)	Vietnam	Mangrove restoration	Secondary and primary using CVM to value non-use	22	Direct use values, indirect use values and non-use values. WTP for non-use values,	Maintenance and protection costs, mangrove restoration	Positive	Yes, to discount rates	Private and communal

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
				values and market methods to value use values						
22	Monela (2005)	Tanzania	FLR through agroforestry and silviculture (Ngitili)	Primary data through expert evaluation and literature review	20	Direct use values (timber and other NTFPs), time saved in collecting firewood and water,	Total project cost for restoration	Positive	Yes, to discount rates	Private and communal
23	Cheboiwo et al. (2019)	Kenya	Afforestation or reforestation of degraded natural forests, Rehabilitation of degraded natural forests, Agroforestry in cropland, Commercial tree and bamboo growing on potentially marginal cropland and un-stocked forest plantation forests, Tree-based buffer zones along water bodies and wetlands, Tree-based buffer zones along roads and restoration of	Expert discussions, activity restoration budgets and extensive review of various land use literature. Benefits and opportunity costs were valued using market prices, avoided	30	Direct (crop harvests, timbers and NTFPs) and indirect use values (carbon sequestration, soil erosion control and increased soil fertility)	Implementation costs, opportunity costs, monitoring and maintenance costs	Positive for the various restoration types considered	Yes, to discount rates	Private and communal

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
			degraded rangelands)	cost/replacement cost and benefit transfer approaches						
24	Ministry of Natural resources, energy and mining-Malawi (2017)	Malawi	Conservation agriculture, agroforestry, FMNR, Community plantations and private woodlots, Natural forest management	Primary data	20	Direct and indirect use benefits	Implementation costs and opportunity costs	Positive for the various restoration types considered	Yes, to discount rates	Private and communal
25	Ministry of Water & Env-Uganda (2016)	Uganda	Reforestation and afforestation, woodlots, Agroforestry, Natural regeneration	Budgets, expert discussions and secondary sources	30	Direct and indirect use benefits	Implementation costs	Positive for the various restoration types	Yes, to discount rates	Private and communal
26	FAO and UNHCR (2018)	Tanzania	Wood-energy rehabilitation (Afforestation and reforestation), Agroforestry, Rehabilitation of degraded native forests	Primary data (field observations, KIIs, FGDs) secondary data	10	Direct benefits (wood fuel) and indirect use benefits (carbon sequestration)	Implementation, operational and opportunity costs	Positive for wood energy plantations and agroforestry but negative for the rest	Yes, to discount rates and wood prices	Private and communal

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
27	Aymeric et al. (2014)	Sudan	SLM through *A. senegal* Agroforestry	Secondary data	25	Direct use benefits (fuelwood and gum arabica) and indirect use benefits (N fixation, avoided nutrient loss, aquifer recharge, carbon sequestration)	Implementation and maintenance costs	Positive	Yes, to discount rates	Private
28	Ministry of Natural resources-Rwanda (2014)	Rwanda	Agroforestry, Well managed woodlots, Natural forest regeneration, protective forests	Primary and secondary data through simulations and predictions	20-30	Direct use benefits (crops, wood) and indirect use benefits (carbon sequestration and erosion control	Implementation, operational and monitoring costs		Yes, to discount rates	Private and communal
29	Tesfaye et al. (2016)	Ethiopia	Soil conservation measures (soil bunds, stone bunds, Fanya juu bunds)	Primary data	27	Yield increment from implementation of bunds	Investment and maintenance costs	Positive	Yes, to investment and maintenance costs and the market price of yield	Private

No.	Paper	Country	Type of restoration	Data source	Years	Benefits	Costs	NPV	Sensitivity analysis	Private or communal
30	Wiskerke et al. (2010)	Tanzania	A small-scale forestation project for carbon sequestration, a short rotation woodlot and a Jatropha plantation	Primary data (expert opinions and field survey) and secondary data	7	Direct benefits (wood fuel, electricity from jatropha, etc.) and indirect benefits (avoided deforestation, improved health, indirect economic benefits)	Production costs and opportunity costs	Positive for woodlots and jatropha for electrification and soap production, negative for forestation for C credits	No	Private and communal
31	Onduru and Muchena (2011)	Kenya	SWC practices such as mulching, zero tillage, stone lines, contour ridges, micro catchments with bananas, terracing and others	Primary data	15	Incremental yield benefits from the adoption of SWC practices	Investment and maintenance costs	Positive	Yes, to discount rates	Private

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